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AIR QUALITY EVALUATION DOWNWIND FROM SWINE FACILITIES

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Summary: Downwind concentrations of hydrogen sulfide and odor from five various swine production systems were measured. On average, for all five sites grouped, hydrogen sulfide concentrations measured at distances <500 ft from the source were 16 ± 35 ppb. At distances greater than 1,500 ft from the source measured hydorgen sulfide concentrations were 3 ± 3 ppb. The overall maximum hydrogen sulfide concentration measured was 140 ppb and this was measured 400 ft downwind from a single-stage lagoon. For distamces greater than 2,000 ft downwind, the maximum hydrogen sulfide concentration measured was 12 ppb, and this was measured 2,850 ft downwind from a deep-pit finishing facility. A strong odor of 15 dilutions to threshold (DT) was measured for 60 percent of the readings taken at or below 1,000 ft downwind. An annoyance odor of 7 DT or greater was measured for 17 percent of the readings taken between 1,000-1,5000 ft downwind, and for 10 percent of the readings taken at downwind distances beyond 1,500 ft. Undetectable levels of hydrogen sulfide and odor were found for all measurements taken not in the downwind plume of the source.

Keywords: hydrogen sulfide, odor, downwind, dispersion

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Abstract

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Introduction

Published literature is lacking that includes simultaneous measurements of source and downwind concentrations of hydrogen sulfide, ammonia, and odor from livestock and poultry production systems. This information is needed to evaluate emission control strategies, to evaluate proposed ambient air quality standards, and to provide calibration data for siting models that have promise in helping site and evaluate new and existing livestock and poultry production systems. This paper summarizes downwind hydrogen sulfide and odor concentrations from five specific swine production systems.

Description of Facilities

The data collected was taken from five specific swine production systems and included in Tables 1 to 5. The data in Tables 1 to 4 were measured at swine systems located in the Midwest. The data in Table 5 was taken from a swine facility located in the south-central United States. The facilities included deep-pit finishing (Table 1), flush-gutter finishing (Tables 2, 5), pull-plug farrowing (Table 4), and flush gutter breeding-gestation and farrowing (Table 3). All lagoons were single stage.

The odor and hydrogen sulfide readings from Table 1 were from a deep pit swine-finishing site. The site has two buildings with a total site capacity of approximately 4,000 head. The building was naturally ventilated with mechanical assist pit fans.

The swine finishing facilities in Table 2 were flush systems from single stage lagoons. Each anaerobic lagoon handles approximately 8,000 head of swine.

The swine breeding-gestation and farrowing in Table 3 is from approximately 2,500 to 3,000 head units. The lagoons are single stage anaerobic lagoons. The effluent is used to flush the gutters periodically.

The swine breeding-gestation and farrowing in Table 4 is from approximately a 2,800 to 3,200 head facility. The unit has a deep-pit breeding-gestation facity and a pull-plug system farrowing facility. The gutters are emptied and cleaned approximately every three weeks between farrowing. The gutter is emptied in the pit under the breeding-gestation facility.

The swine finishing facility in Table 5 was 8 buildings with approximately 900 head per building with a single stage lagoon. The buildings were shallow gutter with pit recharge. The waste handling was a single cell anaerobic lagoon system. The buildings were tunnel ventilated with total slatted floors.

Method of Data Collection

The weather data was taken using a hand-held weather station for recording temperature and wind speed. The sky cover description was observed visually. The wind direction was taken by using a compass with observation of wind direction.

The facilities and manure storage units and the roads surrounding the sites were located on a map. The readings were taken on the road surrounding the swine facilities. The distance from the facility was determined by identifying the location of the readings from an intersection. The odometer reading was taken at the intersection and recorded every 0.1 or 0.5 miles in the area downwind from the production system. This allowed for the distance downwind that the reading was taken.

Scentometer

Odor thresholds were measured on the road around the swine facilities. Odor thresholds on the road were evaluated using a scentometer. The scentometer provides for a mechanism to determine the dilution to threshold (DT) of the air. As an example, if it takes two parts of fresh air to mix with one part of odorous air to just detect an odor the odorous air is said to have an odor threshold of two (DT=2). An odor threshold above seven is often defined as an annoyance odor. An odor threshold at or above 15 is often defined as a strong odor. The larger the number the greater the odor intensity. If an odor was detectable but not identifiable as a source, an odor threshold of 0.5 was recorded. The scentometer allows for an evaluation of the odor plume off the property. It should be recognized that odor moves in a narrow width band in the downwind direction from the source.

Hydrogen Sulfide

Hydrogen sulfide concentration was measured using a Jerome meter manufactured by Arizona instruments. The readings were taken on the roads surrounding the facility. The Jerome meter has a range of detection from 0.001 to 4 ppm (1 to 4,000 ppb). The instrument is portable.

Results: Downwind Hydrogen Sulfide and Odor Measurements

Hydrogen sulfide measurements varied from a low of 0 ppb to an overall high of 140 ppb. A categorization of results, grouped by weather conditions and downwind distance, is given below (note that hydrogen sulfide data was not collected for source five, Table 5):

Day or Night	Sky Conditions	Distance Downwind (ft)	H2S Levels Measured (ppb)
day	cloudy	<= 500	6, 17, 140, 3, 4, 12, 14, 5, 7
		500 to 1,000	na
		1,000 to 1,500	1, 1
		1,500 to 2,000	5
		> 2,000	2, 2, 12, 0, 1, 2, 0, 1, 0, 0, 1, 1, 0, 2, 6, 0
day	clear	<= 500	1, 7, 6, 6, 5, 0
		500 to 1,000	4
		1,000 to 1,500	1, 1, 5, 4
		1,500 to 2,000	na
		> 2,000	0, 7, 7, 0, 0
night	clear	<= 500	na
		500 to 1,000	9, 10
		1,000 to 1,500	na
		1,500 to 2,000	na
		> 2,000	6, 7

na=not available

Grouping all hydrogen sulfide data by distance only, the following summary results were found,

Distance Downwind (ft)	Max (ppb)	Min (ppb)	Average (ppb)	SD (ppb)
< 500	140	0	16	35
500-1,000	10	4	8	3
1,000-1,500	5	1	2	2
> 1,500	12	0	3	3

Dilutions to threshold measurements for downwind odor varied from a low of 0 to a high of 15. A categorization of results, grouped by weather conditions and downwind distance, is given below:

Day or Night	Sky Conditions	Distance Downwind (ft)	Odor Dilutions to Threshold Measured
day	cloudy	<= 500	0.5, 15, 7, 4.5, 15, 2, 7, 7, 0.5, 0.5, 7, 7
		500 to 1,000	na
		1,000 to 1,500	1.5, 1.5
		1,500 to 2,000	2
		> 2,000	0, 4.5, 7, 0, 0.5, 4.5, 2, 2, 1.5, 0.5, 1.5, 0.5, 0.5, 0, 0, 0, 0
day	clear	<= 500	0.5, 11, 15, 15, 2, 2, 15, 2, 7, 2
		500 to 1,000	7
		1,000 to 1,500	2, 7, 0.5, 0.5
		1,500 to 2,000	0, 0.5, 7
		> 2,000	0, 0, 0.5, 2, 2, 0, 0.5, 0
night	clear	<= 500	na
		500 to 1,000	2, 15
		1,000 to 1,500	na
		1,500 to 2,000	na
		> 2,000	2, 7

na = not available

Grouping all odor dilution to threshold (DT) data by distance only, the following summary results were determined,

Distance Downwind (ft)	Max (DT)	Min (DT)	% of readings at or Above 7
< 500	15	0.5	55 (12/22)
500-1,000	15	2	67 (2/3)
1,000-1,500	7	0.5	17 (1/6)
> 1,500	7	0	10 (3/31)

An annoyance-level odor of 7 DT was measured at distances greater than 2,000 ft from the source. At distances between 1,000 and 1,500 feet from the source, 17 percent of the readings were at or above an annoyance odor level of 7 DT. At distances greater than 1,500 feet downwind from the source, 10 percent of the readings were at or above an annoyance odor level of 7 DT. In comparison, at distances greater than 2,000 ft, hydrogen sulfide measurements were on average 3 ppb, which is a level for hydrogen sulfide that is very near the detection (not recognition) threshold. In other words, at 3 ppb of hydrogen sulfide, the olfactory system could detect something other than fresh air but the distinctive smell of hydrogen sulfide could not be recognized. This is one of the major reasons why hydrogen sulfide is not a good indicator for odor. The downwind concentration is almost always below a level that could be recognized by the olfactory system. Other, lower detectable compounds are present in livestock odor which have detection thresholds far lower than hydrogen sulfide. In general, the data shows poor correlation between odor threshold and hydrogen sulfide levels.

As shown in Table 1, when measurements were purposely made away from the downwind plume of the source, as dictated by local weather patterns, neither hydrogen sulfide or odor were detected regardless of the wind speed.

The summary results point out the importance of local weather patterns on the dispersion of gases, especially close to the source. For all measurements taken at downwind distances $\leq$ 500 ft, the average hydrogen sulfide concentration was 23 ppb during day time cloudy conditions with no readings less than 3 ppb. If the daytime conditions were clear and sunny, and the downwind distance was $\leq$ 500 ft, the average hydrogen sulfide concentration was 4 ppb. For distances greater than 500 ft downwind, the average hydrogen sulfide concentration was 2 and 3 ppb, for cloudy and clear sky conditions, respectively. During daytime conditions, solar plays a big role in atmospheric dispersion of gases, especially close to the source. For high solar conditions, representative of day time clear sky conditions, the atmosphere is generally unstable implying that a great deal of turbulence exists in the atmosphere which tends to dilute gases at a high rate close to the source. During daytime cloudy conditons, the atmosphere is more stable and less turbulence is available to mix with emitted air. The measurements point this out quite clearly.

Table 1. Deep pit swine finishing site

							Downwind		Not Downwind	
Month	Time	Temp °F	Solar	Wind Speed (mph)	Direction	Distance Measured (ft)	H_2S (ppb)	Odor Threshold	H_2S (ppb)	Odor Threshold
December	2:15 p.m.	20	Sunny	3 to 5	NW	3700		0		0
February	1:00 p.m.	5	Cloudy	10 to 15	N	5000		0		0
April	4:30 p.m.	57	Cloudy	5 to 8	WNW	3500		2 to 7		0
May	6:00 p.m.	90	Cloudy	15 to 20	WSW	2800	2	7	0	0
May	6:15 p.m.	90	Cloudy	15 to 20	WSW	150		15		0
May	8:15 p.m.	69	Cloudy	0 to 2	Variable (S)	150		0.5		0
June	5:30 p.m.	87	Clear	2 to 4	NW shifting	3700		0		0
July	2:45 p.m.	92	Partly Cloudy	1 to 3	NNW	5200		0		0
July	7:30 p.m.	81	Clear	1 to 3 to calm	NW to N	200	1	0.5	0	0
July	10:15 a.m.	74	Sunny	12-Oct	ESEE	1600		0.5		0
September	5:20 p.m.	70	Partly Cloudy	10 to 15 mph	NNW to N	5200	2	0.5	0	0
October	3:00 p.m.	76	Sunny	8 to 12	S	150	7	7 to 15	0	0
October	3:00 p.m.	76	Sunny	8 to 12	S	2600	0	0.5	0	0
November	4:45 p.m.	52	Partly Cloudy	2 to 3	SW	2850	12	2 to 7	0	0
November	4:45 p.m.	52	Partly Cloudy	2 to 3	SW	500	17	7	0	0
December	11:00 a.m.	48	Partly Cloudy	10 to 15	S	150	6	2 to 7	0	0

Table 2. Downwind from lagoon and swine finishing buildings

							Downwind lagoon		Not Downwind	
Month	Time	Temp °F	Solar	Wind Speed (mph)	Direction	Distance Measured (ft)	H_2S (ppb)	Odor Threshold	H_2S (ppb)	Odor Threshold
July	10:20 a.m.	69	Cloudy	1 to 3	ESE	4000	0	2		
August	3:00 p.m.	87	Sunny	1 to 3	SW	700	4	7		
August	3:15 p.m.	87	Sunny	1 to 3	SW	1100		2		
September	8:15 a.m.	74	Fog	1 to 3	ESE	3200	1	2		
September	8:30 a.m.	74	Fog	1 to 3	SE	1500	1	1.5		
July	1:00 p.m.	85	Cloudy	1 to 2	S	3000	2	1.5		
August	6:00 p.m.	83	Sunny	1 to 3	SW	350	6	15		
August	6:15 p.m.	83	Sunny	1 to 3	SW	200	6	15		
August	6:30 p.m.	83	Sunny	1 to 3	SW	1800		7		
August	3:00 p.m.	87	Sunny	1 to 3	SW	1400	5	7		
August	3:15 p.m.	87	Sunny	1 to 3	SW	200	5	2		
September	11:00 a.m.	80	Partly Cloudy	1 to 3	S	3000	0	0.5		
March	8:25 p.m.	34	Clear	8 to 12	SW	1000	10	15		
March	8:40 p.m.	34	Clear	8 to 12	SW	2600	7	7		
March	8:50 p.m.	34	Clear	8 to 12	SW	3400	6	2		
March	8:15 a.m.	41	Clear	2 to 4	SW	1000	9	2		

Table 3. Downwind from lagoon and swine farrowing buildings

							Downwind lagoon		Not Downwind	
Month	Time	Temp °F	Solar	Wind Speed (mph)	Direction	Distance Measured (ft)	H_2S (ppb)	Odor Threshold	H_2S (ppb)	Odor Threshold
July	7:15 p.m.	79	Cloudy	2 to 3	E	400	140	15		
August	9:00 a.m.	80	Sunny	1 to 3	S	1200	4	0.5		
September	8:00 a.m.	70	Fog	2 to 3	E	2600	1	1.5		
September	9:10 a.m.	75	Clearing	1	NE	400	0	2		
September	3:15 p.m.	85	Partly cloudy	1 to 3	SE	Berm Nside	12	7		
September	3:20 p.m.	85	Partly cloudy	1 to 3	SE	Berm Wside	14	7		
September	3:25 p.m.	85	Partly cloudy	1 to 3	SE	Berm Eside	4	0.5		
September	3:25 p.m.	85	Partly cloudy	1 to 3	SE	Berm Sside	3	0.5		
July	4:00 p.m.	78	Cloudy	0 to 1	E	2650	0	0.5		
August	10:00 a.m.	80	overcast	1 to 2	NW	1600	5	2		
September	6:00 p.m.	87	Fog	1	S	2600	0	0.5		
July	5:00 p.m.	76	Overcast	1 to 2	NE	3600	1	2		
July	5:15 p.m.	76	Overcast	1 to 2	NE	1200	1	1.5		
August	12:30 p.m.	83	Hazy	1	W	120	7	7		
August	12:45 p.m.	83	Hazy	1	W	120	5	7	Bldg	
September	3:00 p.m.	88	Partly Cloudy	3 to 5	E SE	2700	1	0.5		

Table 4. Downwind from deep pit breeding -gestation sow unit with pull-plug farrowing

							Downwind		Not Downwind	
Month	Time	Temp °F	Solar	Wind Speed (mph)	Direction	Distance Measured (ft)	H_2S (ppb)	Odor Threshold	H_2S (ppb)	Odor Threshold
May	11:15 a.m.	60	Sunny	10 to 15	NW	2100	7	2	0	0
May	11:20 a.m.	60	Sunny	10 to 15	NW	2600	7	0	0	0
June	6:00 p.m.	79	Cloudy	2 to 4	NW	4700	0	0	0	0
June	6:30 p.m.	79	Cloudy	2 to 4	NW	2600	2	0	0	0
June	12:20 p.m.	82	Partly Cloudy	10 to 15	WSW	4700	6	0	0	0
July	11:15 a.m.	87	Sunny	2 to 8	SSW	2600	0	0.5	0	0
September	6:10 a.m.	51	Clear	2 to 4	ENE	2900	0	0	0	0
November	11:50 a.m.	70	Cloudy	10 to 15	SW	5200	0	0	0	0

Table 5. Downwind from lagoon and swine finishing buildings

Month	Time	Temp °F	Solar	Wind Speed (mph)	Direction	Distance Measured (ft)	Downwind lagoon H_2S (ppb)	Odor Threshold
April	4:50 p.m.	50	Cloudy	2 to 4	NE	2200		1.5
April	12:30 p.m.	65	Cloudy	2 to 4	NW	2400		1.5
April	8:45 a.m.	56	Sunny	1 to 3	ENE	400		2
April	9:01 a.m.	57	Sunny	1 to 3	ENE	1600		0
September	9:18 a.m.	78	Sunny	1 to 3	NE	400		2
September	11:17 a.m.	85	Sunny	1 to 3	N	1200		0.5
November	3:15 a.m.	47	Sunny	2 to 4	S	150		15 (Bldg)
November	7:30 a.m.	50	Sunny	2 to 4	SE	200		2
November	8:40 a.m.	58	Sunny	3 to 5	SE	200		7
February	8:53 a.m.	47	Sunny	2 to 4	N	200		2